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Greening the operating room

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ABSTRACT

Background: Climate change will affect most populations in the next decades and put the health of billions of people at risk. Health care facilities represent a significant source of pollution around the world and contribute to environmental changes. To address this topic, we performed a review of the available literature on tactics to reduce operating room (OR) waste and the potential of these strategies to impact the environment.
Data Sources: A literature search was performed querying PubMed, Web of Science, and Science Direct. No comparative data were found; most were opinion papers, white papers, and case studies. For this reason, we proceeded with a narrative review, which provides an overview of the evidence on this topic and identifies areas for future research.
Results: This systematic review summarizes the available literature on the 5 "Rs" of waste management: reduction, reusing, recycling, rethinking, and renewable energies.
Conclusions: Surgery has a unique opportunity to transition to more environmentally-friendly operating room strategies, which may help decrease waste and lessen the impact of climate change.
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Introduction

Climate change, i.e. global warming, will affect most populations in the next decades and put the health of billions of people at increased risk.[1] Ironically, health care facilities represent a significant source of pollution around the world and, therefore, contribute to environmental changes associated with global warming.[2]

A study by Chung and Meltzer in 2009[46] estimated the carbon footprint of the US health care sector, which was shown to contribute with 8% of the nation's greenhouse gas emissions both from health care activities directly as well as from activities associated with the supply chain of health care-related goods and services. Another study on the environmental impact of US health care from Eckelman and Sherman in 2013[47] indicated that relevant fractions of national air pollution emissions and consequences was attributable to the healthcare sector, including acid rain (12%), greenhouse gas emissions (10%), smog formation (10%) criteria air pollutants (9%), stratospheric ozone depletion (1%), and carcinogenic and non-carcinogenic air toxics (1–2%).

In addition, the sheer amount of, and overall toxicity of, medical waste has increased in recent decades. Certain medical products contribute significantly to pollution and contamination of the food chain from bio-accumulative toxins. As a prime example, medical waste incinerators are among the top 5 sources of mercury and dioxin emissions in the United States.[3]

Although the topic of the environment may not be a common concern to many surgeons, it is of increasing importance to the communities that they serve and to the medical centers within which they work. Therefore, a movement toward "greening" health

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care, or improving the environmental footprint of health care, has been building. Individual hospital-based initiatives have been reported over the past decade, with strategies to successfully reduce medical waste while not increasing operating cost.[11]

During the past 50 years, the healthcare industry has undergone tremendous changes in the types of products it uses and the waste it produces. For example, the industry quickly adopted disposable, typically plastic, products. Historically, there were few regulations for dealing with medical wastes separate from other waste because most hospitals had their own incinerators and incinerated everything. With the increased awareness of infectious diseases, particularly HIV and Hepatitis, more regulations have been initiated regarding safe hospital waste disposal of materials contaminated or potentially contaminated by bodily fluids, such as blood, saliva, or intestinal fluid. Both the introduction of universal precautions standards in 1987 and the adoption of the Medical Waste Tracking Act, signed into law in 1988, set in motion a movement to treat most medical waste, regardless of toxicity or type, as infectious in nature, in an effort to protect the public.

Because of this, there was a dramatic increase in the amount of waste labeled as infectious requiring special 'red bag' disposal, most of which underwent incineration. In theory, 'red bag' disposal should comprise solid or liquid items contaminated with blood or other potentially infectious material (human bodily fluids including semen, vaginal secretion, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, peritoneal fluid, amniotic fluid, and saliva). However, this type of disposal tends to get overused when a great amount of waste that does not require special treatment is placed in red bags due to availability (having a red bag in the room) and careless unplanned waste separation.

Recycling became a growing phenomenon in the United States, with 34.7% of all waste successfully recycled in 2011, representing an increase from 16% in 1990 and 28.5% in 2000.[4] However, health care centers continue to be the second largest contributors to waste in the United States, with >4 billion tons of waste produced per year.[5] Data from single center studies shows that more than 50% of general operating room (OR) waste is uncontaminated and potentially recyclable, but is incorrectly disposed of as contaminated or hazardous waste by OR staff.[6] This is often due to lack of staff education on waste segregation and treatment cost of each type of waste, leading to irrational unplanned waste disposal on unintended material for each disposal bag.

Longer surgical cases can generate up to 50 pounds of waste, and orthopedic and cardiac procedures can produce upward of 100–200 pounds of waste per case.[7] As ORs and labor-delivery (L&D) suites account for over 50% of all hospital waste, initially targeting ORs to decrease overall waste production through a combination of initiatives such as reprocessing single-use instruments, decreasing the amount of disposables opened within a case, educating staff on classification of waste products, and recycling, can have the largest impact to decrease overall medical waste.

To investigate this topic, we performed a narrative review of the literature around sustainability in the Operating Room to better inform action plans for impactful 'greening' the ORs.

Materials and methods

An experienced research librarian performed a search of the relevant literature in September 2017, querying PubMed, Web of Science, and Science Direct using the following search terms combined with "operating rooms" and "surgical theaters": "green", "waste reduction", "reuse", "recycle", "solar", "wind power", "sustainable", "hydropower", "biothermal", "rethinking", and "repurposing". A total of 161 citations were found. The abstracts and titles were screened for relevance and consideration for quantitative review with meta-analysis or qualitative systematic review. We excluded 124 articles for lack of relevance to our topic; these included articles on the technical aspects of incineration, technical aspects of instrument sterilization, and other tangential topics. The remaining 37 articles were included in this review. No comparative data were found; most published papers were opinion papers, white papers, and case studies. For this reason, we proceeded with a narrative review, which provides an overview of the state of the science on this topic and identifies areas for future research.

Results

Our review summarizes the available literature on reduction, reusing, recycling, rethinking, and renewable energies. This is based on recommendations made by the Association of periOperative Registered Nurses' (AORN). **Reduction** (i.e. proper waste segregation, reusable sharps container, fluid waste management, energy expenditure, LED surgical lamps, greener equipment packaging), **Reuse** (i.e. reprocessing of single-use devices, reusable surgical linens), **Recycling** clean plastic and paper, **Rethinking** (i.e. anesthetic gas reclamation), **Research** (life cycle analyses of materials, cost comparison of technologies and development of "green" devices) and use of **Renewable energies** (i.e. photocatalytic membrane reactors (PMR) to degrade cytostatic drugs, electrochemistry methods; microbial strains with different oxygen requirements, Biogas for heat and power production, subdermal solar cells to absorb light transmitted through skin to power medical electronic implants in bodies).[8–10] Future research for each is addressed in our discussion.

Reduction

Reduction concerns methods that decrease the waste of environmental resources as well as decreasing the amount of disposable waste produced. Important methods include reducing energy and water usage (turning off OR lights and equipment when not in use), abolishing dispensable items such as redundant packing in products, and minimizing the occurrence of unnecessarily opened materials.

A study by Gitelis M. et al.[44] showed the impact of surgeon education on waste and cost reduction. Information concerning disposable supply costs in three common operations (laparoscopic cholecystectomy, laparoscopic appendectomy, and open inguinal hernia repair) was presented to the departments of general surgery and surgical oncology in a departmental meeting. At the end of the presentation, surgeons agreed to attempt cost reduction without compromising patient care. The study revealed that after the intervention the average cost of disposable supply equipment used in a single laparoscopic cholecystectomy decreased from $589 to $531 ($p < 0.001$), representing a 10% cost reduction per case and $33,000 annually.

Another study by Chasseigne V. et al.[45] in a French University Hospital evaluated the burden of wasted supplies (opened unused devices) in the operating room for digestive, urologic, and gynecologic surgeries. Wasted supplies comprised up to 20.1% of the total cost allocated to surgical supplies, which could imply in a 100,000 euros worth of cost savings annually. The most common reason of wastage was an anticipation of the surgeon's needs, and 68% of participant who responded to the study's questionnaire acknowledged that being educated on supply prices would change their behavior.

Additionally, while not specifically described as a solution in any of our reviewed literature, limiting foot traffic and materials brought into the OR is a sensible way to decrease waste, as anything brought into the OR must be either decontaminated or removed at

the end of the case. These are solutions that not only environmentally friendly, but also financially smart in private, regional, and global settings.

Reuse

Reuse which concerns the substitution of disposable materials for reusable ones, leading to less solid waste production and less use of natural resources. Some examples include drapes (disposable textile), gowns (disposable textile), OR packages (disposable drapes), OR paddings (foam reusable gel pads), suction tubes (plastic disposable tubes), as well as some more specialized material such as coronary sinus cardioplegia cannula.

The use of disposable versus reusable materials is closely related to each country/region culture and customs. Decisions in many cases are based on a combination of cost and scientific data. However, when looking for scientific data on infection rates when comparing both materials, there is still wide controversy. A few studies from the 1960s–1980s indicated higher incidence of infection associated with reusable textiles[12–14] but these were small studies that were not randomized or appropriately controlled. Other studies[15–19] and World Health Organization guidelines[18] report no difference between disposable and reusable materials in surgical site infections or wound contamination.

Overall, it is crucial to study this area so that we can accurately quantify infection rates and total costs (including price of material + cleaning methods + labor) for disposable versus reusable materials. To date, there have been no comparative studies of cost savings versus expenditures to critically evaluate this important topic.

Recycling

The OR is an environment with a great amount of the waste produced being qualified for recycling. Nonetheless, recycling in the OR setting is usually not performed adequately.

Waste can be segregated into different categories, as seen in Table 1. This separation is not only important from an environmental standpoint, but also from an economical one given that clinical waste is the most expensive to treat.

Considering that the operating room is responsible for much of the waste production in the hospital environment, it is necessary to inspect waste segregation in the OR. A study conducted in 6 ORs in Australia[20] observed that in 237 operations during a week time 1265 kg of waste was produced (45% general waste, 32% infectious waste, and 23% recyclables). Of all material designated as recyclable, only 55% was recycled. In addition, the costs for common waste and recycling disposal were found to be similar.

Although recyclable materials represent an important amount of OR waste, there are still many obstacles to correct waste segregation. One study performed among 780 anesthesiologists from Australia, New Zealand and England regarding recycling in the OR[21] found that only 11% of participating anesthesiologists agreed that appropriate and adequate recycling occurred in their ORs. The main barriers found to OR waste recycling in this study were inadequate recycling facilities (49%), negative staff attitudes (17%), and inadequate information on how to recycle waste (16%).

Recycling and donation of surgical supplies to developing countries

Basic surgical procedures are among the most cost-effective of all health interventions in developing countries. If they were more widely available, essential surgical procedures could prevent 1.5 million deaths a year.[22,23] Not until recently has surgery been considered an integral part of public health in developing countries.[23] Nonetheless there is real need for basic surgical medical supplies in third world countries on routine bases which is exacerbated during emergencies or medical disasters relief.[24,25] Given that much surgical waste comes from partially used prepackaged sterile operative sets,[24] this may be an area where a greener OR and global surgical work may intersect.

Surgical missions have been for years an efficient but limited way to deliver surgical supplies to countries in need. Along with the sharing of surgical skills, the delivering of operative medical supplies has been an important component of the success of such missionary work. Most of the physician-lead surgical missions collect supplies donated from their respective institutions. Some institutions may provide near expiration date dressings, gauze, intravenous kits, antimicrobial scrubs, or tubing supplies. Others collect disposable surgical instruments that could be re-sterilized and donated. In addition to reutilization of otherwise supplies that will be discarded, the in-field missionary experience provides participating surgeons, residents and medical personal with a heightened appreciation of the limited resources and enhanced their creativity, such as using sterile instrument wrapping as sterile drapes for procedures and conscientious use of sutures or staple use.

In the earliest 1990's InterVol established a regional pilot program in Rochester, N.Y., to evaluate the feasibility of collecting and shipping unused medical supplies from the health-care facilities in the local areas, to countries in need. It helped hospitals to dispose reusable medical supplies while providing direct support to Third World hospitals and volunteers medical teams.[26] They created a database to study ways of limiting unused materials that needed to be discarded. The program included, setup and education, collection, sorting and inventory, and distribution. The program was proved to be effective and could be used as model by other institutions.[24,26] Other organizations such as MedWish will repurpose discarded medical supplies and equipment to provide humanitarian aid in developing countries.[27]

One must be aware that although donors' intentions are in good faith, if there is lack of awareness of the local realities or politics of the intended beneficiaries, this could lead to unforeseen consequences of the donation at the recipient's end. The World Health Organization recommends four principles of a good medical equipment donations: respect the recipient's request, assure the donation will benefit the recipient, keep an open line of communication; and ensure quality.[28]

Table 1
Waste categories and specifications.

Waste Category	Examples
Common waste	Food waste, biodegradable plastics
Clinical waste	Regulated medical waste (infectious or pathogenic, i.e. gloves, aprons, swabs, dressings, wipes, catheters, waste from body fluids), sharps (must be disposed of in specialized sharps containers), and pharmaceutical material
Recycling	Non-contaminated paper, cardboard, steel and aluminum packaging, plastics, non-contaminated wrapping material
Radioactive waste	Contaminated with radioactive material

In addition to repurposing supplies, the materials themselves may also be recycled.

Although paper can be recycled only four to six times, metal and glass can be recycled unlimited times without affecting quality.[29] And even recycling steel from single-use laryngoscope blades and Magill forceps has been also been advocated.[30]

Rethinking/reclamation

The World Health Organization has named the capture of inhaled anesthetics as one of its strategies for Health and Sustainable Development. Anesthetic gases, when released into the atmosphere, not only can cause health risks to exposed workers, they are also extremely powerful global warming pollutants.[31] The anesthetic agents used today are volatile halogenated ethers and the common carrier nitrous oxide. All of these agents are known to be aggressive greenhouse gases. As less than 5% of the total delivered anesthetic is actually metabolized by the patient, the vast majority of these agents are vented to the atmosphere through whatever operating room scavenging system is in place. Nitrous oxide is a particularly large contributor with an estimated 7% impact on human induced climate change.[32] However, the precise contribution of volatile agents to global warming and climate change had not been previously well studied. In 2010, a group out of Michigan and the Jet Propulsion Laboratory in Pasadena undertook a study to estimate the global warming potentials (GWP) of three widely used inhaled anesthetic agents. Using data they collected to understand the atmospheric chemistry of these agents and their radiative properties, they were then able to project the climatic impact of the use and release of these agents. Based on their collected data and calculated estimates, the global emissions of inhalation anesthetics have a climate impact comparable to that of the CO_2 emissions from one coal-fired power plant or 1 million passenger cars.[33]

Given these impacts of anesthetic gases on global warming, several strategies have been proposed to decrease the release of these gases. The Ontario Hospital Clean Air Challenge encourages investigating how to remove the volatile halocarbons of waste anesthetic gases before they are vented to the atmosphere.[33] Their suggestions include the use of scavenging systems, capture technology to collect anesthetics, and waste reduction. Blue-Zone technology is also a technology to capture, reclaim and purify halogenated anesthetic gases. A group in Tennessee has done initial clinical trials testing a new technology that combines efficient anesthetic gas scavenging with cold-trap condensation of waste anesthetic gas. This system was able to extract at 99% efficiency with a relatively low cost.[34] Xenon has been proposed as an alternative anesthetic gas with low toxicity, and no atmospheric impact. However, it is very expensive to manufacture.[33] With additional research and proper use, it may be one strategy to decrease the global warming impact of anesthetic gases.

Renewable energy

Maintaining a sterile environment, reliable energy resources for 24 h a day, and providing ambient conditions is paramount for hospitals to provide effective patient care. This is especially exemplified in the operating room, where sterility of equipment, negative pressure rooms with specific temperature ranges, and bright operating fields all help improve patient outcomes and facilitate operative techniques. While hospital and surgical environments have been maximized to provide effective care, little consideration into the environmental impacts have been made.

While large hospitals alone account for less than one percent of commercial buildings, the U.S. Energy Information Administration demonstrated that in 2003, they consumed over 10% of energy in the commercial sector.[35] This equates to 594 trillion BTU. The function for which energy is being used varies tremendously based on various factors including: age the building was constructed, size of structure, and type of healthcare edifice. Major sources of fossil fuel utilization include reheat and heating, lighting, supply/return/exhaust fans, chillers, pumps, medical imaging, elevators, humidification, etc.[36] Of the energy used by healthcare systems, less than five percent is derived from renewable energy sources, with the other sources, greater than 95%, stemming from petroleum, natural gas, coal, and nuclear power.[37]

Renewable energy includes any source of energy that can be naturally replenished and is inexhaustible on small-frame time scale. Examples include solar, wind, hydropower, geothermal, and bioenergy. This is in comparison to energy from fossil fuels which take millions of years replenish. Not only are fossil fuels not readily replenished, but they create greenhouse gases which are detrimental to our atmosphere. With the ability to run the entire world on renewable energy sources, many countries are slowly making the switch to become “greener”.

Investments in renewable energy sources are not only efficacious for a healthy environment, but various health care systems are seeing monetary benefits as well.

According to ENERGY STAR, a program of the U.S. Environmental Protection Agency and Department of Energy, an average Healthcare system's expenditure for energy is over $6.5 billion.[38] Millions of dollars in savings can be accrued by reducing energy expenditure costs by 0.1%.[39] PeaceHealth, a hospital system on the west coast; Gundersen Health System, situated in various states; New York Presbyterian Hospital; and Providence Health and Services, based in Washington, are examples of this with reported savings of $800,000 to over $3 million dollars annually, by implementing energy-efficient plans.[40–43]

Discussion

The present article portrayed the current scenario of sustainability observed in the operating room environment through a wide narrative review. Previously implemented and successful strategies were discussed, as well as failed programs and future perspectives and intentions. We found that one of the most relevant obstacles to executing new plans of action consist in adapting them to the current operating room routine, always being attentive to achieving the best patient healthcare.

Some investigators have proposed the creation of Green Operating Room Committees to increase knowledge, improve attitudes, and facilitate the success of green initiatives.[39] For such environmental initiatives (reduce, reuse, recycle) to generate tangible results in the OR it is ideal that all the operative and perioperative team get involved, including surgeons, anesthesiologists, residents, and nurses (perioperative, circulating and scrub nurses). A multidisciplinary approach is essential to identify aspects that can be improved and to create feasible action plans.

All of the initiatives discussed above leave tremendous opportunities for research on the impact they can have on greening the operating room. Organizations such as Practice Greenhealth[41] can serve as educational resources and collaborative resources for ideas exchange. Their “Greening the OR” initiative provides hospitals and health care organizations with the tools and support they need to start making an environmental impact in their own ORs. Health Care Without Harm is another international organization seeking to reduce the environmental impact of the health care industry.[42] The Green Guide for Health Care[43] is a project of Health Care Without Harm, which shares best practices for creating high performance healing environments.

The limitations of this study include the analysis of limited previous literature and poor data sources, given that most references comprised of opinion papers, white papers, and small case studies. Nevertheless, this study stands out as the most comprehensive overview of the topic up to date, encompassing various sustainability topics.

The study and analysis of methods to increase sustainability in the operating room setting, as well as other healthcare environments and facilities, is crucial. The burden of healthcare in the country's overall waste production is extremely relevant, which means that each new project implemented can have a great overall impact in the environment. Future research such as prospective studies are needed to expand ongoing and new sustainability projects, testing cost-effectiveness and associated impact on patient safety and healthcare. With respect to cost-savings, cost-containment, and financial incentives–including tax benefits for "green" initiatives, these must be closely examined and quantified, as few organizations will have the resources to direct time and money away from patient care toward the health of the planet. Finally, regulatory and policy issues may emerge within this developing aspect of healthcare.

Conclusions

This study provides a comprehensive narrative review of current practices and opportunities to improve sustainable operating room practices that could reduce waste, contribute to global surgery initiatives, and contain costs. Given the paucity of data in this area, more research is needed to guide evidence-based practice.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.amjsurg.2018.07.021.

References

1. Costello A, Abbas M, Allen A, et al. Managing the health effects of climate change. *Lancet*. 2009;373(9676):1693–1733.
2. Shinn HK, Hwang Y, Kim BG, et al. Segregation for reduction of regulated medical waste in the operating room: a case report. *Korean J Anesthesiol*. 2017;70(1):100–104.
3. Kaiser B, Eagan PD, Shaner H. Solutions to health care waste: life-cycle thinking and "Green" purchasing. *Environ Health Perspect*. 2001;109(3):205–207.
4. Agency EP. Municipal solid waste generation, recycling, and disposal in the United States: facts and figures for 2011-2013 [Accessed 12/1/2017 from: https://nepis.epa.gov]
5. Albert MG, Rothkopf DM. Operating room waste reduction in plastic and hand surgery. *Plast Surg (Oakv)*. 2015;23(4):235–238.
6. Wyssusek KH, Foong WM, Steel C, Gillespie BM. The gold in garbage: implementing a waste segregation and recycling initiative. *AORN J*. 2016;103(3):e1–e8, 316.
7. Penn E, Yasso SF, Wei JL. Reducing disposable equipment waste for tonsillectomy and adenotonsillectomy cases. *Otolaryngol Head Neck Surg*. 2012;147(4):615–618.
8. Melamed A. Environmental accountability in perioperative settings. *AORN J*. 2003;77(6):1157–1168.
9. Chen P, Wang YX, Yan L, et al. Feasibility of biohydrogen production from industrial wastes using defined microbial co-culture. *Biol Res*. 2015:48.
10. Solli L, Havelsrud OE, Horn SJ, Rike AG. A metagenomic study of the microbial communities in four parallel biogas reactors. *Biotechnol Biofuels*. 2014:14.
11. Kwakye G, Brat GA, Makary MA. Green surgical practices for health care. Arch Surg, 201;146(2).
12. Moylan JA, Kennedy BV. The importance of gown and drape barriers in the prevention of wound infection. *Surg Gynecol Obstet*. 1980;151:465–470.
13. Moylan JA, Fitzpatrick KT, Davenport KE. Reducing wound infections: improved gown and drape barrier performance. *Arch Surg*. 1987;122:152–157.
14. Baldwin BC, Fox IL, Russ C. Affect of disposable draping on wound infection rate. *Va Med*. 1981;108:477.
15. Garibaldi RA, Maglio S, Lerer T, Becker D, Lyons R. Comparison of nonwoven and woven gown and drape fabric to prevent intraoperative wound contamination and postoperative infection. *Am J Surg*. 1986;152:505–509.
16. Williams CPS, Oliver TK. Nursery routines and staphylococcal colonization of the newborn. *Pediatrics*. 1969;44:640–646.
17. Albert NM, et al. Infection rates in intensive care units by electrocardiographic lead wire type: disposable vs reusable. *Am J Crit Care*. 2014;23(6):460–467.
18. Global Guidelines for the Prevention of Surgical Site Infection. *Appendix 17, Summary of the Systematic Review on Drapes and Gowns*. Geneva: World Health Organization; 2016. from https://www.ncbi.nlm.nih.gov/books/NBK401142. Accessed January 12, 2017.
19. Bellchambers J, Harris JM, Cullinan P, Gaya H, Pepper JR. A prospective study of wound infection in coronary artery surgery. *Eur J Cardiothoracic Surg*. 1999;15:45–50.
20. McGain F, Jarosz KM, Nguyen MN, Bates S, O'Shea CJ. Auditing operating room recycling: a management case report. *A A Case Rep*. 2015 Aug 1;5(3):47–50.
21. McGain F, White S, Mossenson S, Kayak E, Story D. A survey of anesthesiologists' views of operating room recycling. *Anesth Analg*. 2012;114(5).
22. International collaboration for essential surgery [Accessed 12/1/2017 from: http://www.essentialsurgery.com/]
23. OpEd. Surgery could save millions of lives in developing countries the World Bank. from http://www.worldbank.org/en/news/feature/2015/03/26/surgery-could-save-millions-of-lives-in-developing-countries; March 25, 2015. Accessed January 12, 2017.
24. Pennino R, Mayer AM, Dahn AT, Husser W. Recycling unused medical supplies: a surgeon's response. *Plast Reconstr Surg*. 1994 Aug;94(2):397–399.
25. Jenny AM, Li M, Ashbourne E, Aldrink M, Funk C, Stergachis A. Assessment of the scope and practice of evaluation among medical donation programs. *Glob Health*. 2016 Nov 4;12(1):69.
26. InterVol. Sustainable solutions for worldwide healthcare. from https://www.intervol.org/. Accessed January 12, 2017.
27. MedWish: Repurpose, save lives [Accessed 12/1/2017 from: www.medwish.org]
28. World health organization guidelines for health care equipment donations [Accessed 12/1/2017 from: http://www.who.int/hac/techguidance/pht/1_equipment%20donationbuletin82WHO.pdf]
29. Wyssusek KH, Foong WM, Steel C, Gillespie BM. The gold in garbage: implementing a waste segregation and recycling initiative. *AORN J*. 2016 Mar;103(3):316. e1-8.
30. Enzor NA, Pierce JM. Recycling steel from single-use laryngoscope blades and Magill forceps. *Anaesthesia*. 2013 Jan;68(1):115–116.
31. World Health Organization: Capture of inhaled anaesthetics.[Accessed 12/1/2017 from: http://www.who.int/sustainable-development/health-sector/strategies/inhaled-anaesthetics/en/]
32. Gadani H, Vyas A. Anesthetic gases and global warming: potentials, prevention and future of anesthesia. *Anesth Essars Res*. 2011;5(1):5–10.
33. Sulbaek Andersen MP, Sander SP, et al. Inhalation Anasethetics and climate change. *Br J Anaesth*. 2010;105(6):760–766.
34. Berry J, Barwise J, Lancaster L. Reclaiming Waste anesthetic gas: initial clinical trials: 3AP8–3. *Eur J Anaesthesiol*. 2007;24:32.
35. Annual Energy Review. Total energy. U.S. Energy information administration, U.S. Department of energy. from https://www.eia.gov/totalenergy/data/annual/#consumption; 2011. Accessed January 12, 2017.
36. Sheppy M, Pless S, Kung F. Healthcare energy end-use monitoring. [White paper]. National renewable energy laboratory, U.S. Department of energy. from https://energy.gov/sites/prod/files/2014/09/f18/61064.pdf; 2014. Accessed January 12, 2017.
37. Commercial Buildings Energy Consumption Survey. 2012 CBECS survey data. U.S. Energy information administration, U.S. Department of energy. from https://www.eia.gov/consumption/commercial/data/2012/#b22-b33; 2015. Accessed January 12, 2017.
38. Energy Smart. U.S. Department of energy. No date. Healthcare: an overview of energy use and energy efficiency opportunities.[Accessed 12/1/2017 from: https://www.energystar.gov/ia/partners/publications/pubdocs/Healthcare.pdf]
39. Wormer BA, et al. The green operating room: simple changes to reduce cost and our carbon footprint. *Am Surg*. 2013;79(7):666–671.
40. Health Research & Educational Trust. (2014, May). Environmental Sustainability in Hospitals: The Value of Efficiency. Chicago, IL: Health Research & Educational Trust. [Accessed 12/1/2017 from: http://www.hpoe.org/Reports-HPOE/ashe-sustainability-report-FINAL.pdf]
41. Practice Greenhealth [Accessed 12/1/2017 from: https://practicegreenhealth.

org/about/mission]
42. Health Care without Harm [Accessed 12/1/2017 from: https://noharm-uscanada.org/content/us-canada/about-us]
43. Green Guide for Health Care [Accessed 12/1/2017 from: http://www.gghc.org/]
44. Gitelis M, Vigneswaran Y, Ujiki MB, et al. Educating surgeons on intraoperative disposable supply costs during laparoscopic cholecystectomy: a regional health System's experience. *Am J Surg*. 2015. https://doi.org/10.1016/j.amjsurg.2014.09.023.
45. Chasseigne V, Leguelinel-Blache G, Nguyen TL, et al. Assessing the costs of disposable and reusable supplies wasted during surgeries. *Int J Surg*. 2018. https://doi.org/10.1016/j.ijsu.2018.02.004.
46. Chung JW, Meltzer DO. Estimate of the carbon footprint of the US health care sector. *J Am Med Assoc: JAMA, J Am Med Assoc*. 2009;302(18):1970.
47. Eckelman MJ, Sherman J. Environmental impacts of the U.S. Health care system and effects on public health. *PLoS One*. 2016;11(6), e0157014. https://doi.org/10.1371/journal.pone.0157014. Ahmad S, ed.